ECOLOGICAL RESTORATION THROUGH SILVICULTURE—A SAVANNA MANAGEMENT DEMONSTRATION AREA, SINKIN EXPERIMENTAL FOREST, MISSOURI

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Abstract—In 1998, a project was initiated to demonstrate techniques and evaluate the efficacy of reducing overstory tree density and reintroducing fire in order to develop the tree composition, structure, and herbaceous complex typical of a savanna. On three study areas, two dominated by oak and one by shortleaf pine, the total basal area of all trees = 1.6 inches DBH was thinned to approximately 40 feet^2 basal area per acre during the 1998-99 dormant season. Prescribed burns were conducted in April 1999 and April 2000. After assessing mortality from the fire, the residual basal area was adjusted to 35 feet^2 per acre during the 1999 growing season.Pretreatment inventories conducted during August of 1998 tallied over 45 herbaceous and woody understory species. During the first-year post-treatment inventory (August 1999), 20 new herbaceous species were identified on the treatment plots. Following the second prescribed fire, 17 additional herbaceous species were tallied (August 2000). The most abundant of these species were fireweed and pokeweed. Of the woody understory species (<1.6 inches DBH) present on the sampling plots, only the oaks and hickories did not exhibit a substantial change in the number of stems per acre following treatment. Blackhaw was eliminated from the understory following the prescribed burn and the numbers of black cherry, red maple, dogwood, and shortleaf pine decreased by more than 50 percent. Species that benefited from the treatment included black gum (+210 percent), sassafras (+40 percent), sumac (+2110 percent), and post oak (+494 percent). Initial treatments greatly modified the overstory structure and, thus, the understory light regime. This in turn has affected an immediate and marked shift in the understory complex of herbaceous and woody plants.

INTRODUCTION

Management and restoration of savannas has become a topic of considerable interest in recent years. These are among the most diverse systems in the Northern Temperate Zone, but have declined in area by over 99.9 percent during the last 100 years (Nuzzo 1986). Much of this reduction has been due to changes in land use across the Midwest (e.g. agricultural conversion). However, in many areas including the Ozark Highlands, over the last 50-100 years fire suppression has caused a marked reduction in small diameter tree mortality. This in turn has affected a change from savanna to closed canopy forest with a corresponding reduction in herbaceous species diversity as understory light levels diminished (Jenkins 1997).

If fire was the primary disturbance factor that maintained savanna ecosystems on the landscape and suppression of this disturbance caused a change in the basic makeup of the system, then one might expect that the reintroduction of fire should restore the ecosystem to its original structure and function. Unfortunately, this has not proven to be the case, at least not within a reasonably short time frame. In an attempt to restore pre-settlement structure and composition in a Missouri oak forest, Blake and Schuette (2000) reported that reintroduction of regular prescribed fires had no effect on overstory species composition or structure after 10 years. Similar results were reported after 15 years in Minnesota (White 1986) and after 20 years in Illinois (Taft and others 1995). Although reintroduction of a fire regime greatly reduced the shrub layer and the number of small diameter trees (Blake and Schuette 2000, White 1986) the effect on large diameter canopy dominant trees was slight. These trees tend not to be affected by low intensity prescribed fire. In order to recreate pre-settlement conditions using fire alone, either higher intensity burns would need to be used (with the associated risk of a stand replacing fire or escape of the burn onto adjacent property) or sufficient time would need to pass for natural mortality to occur within the dominant canopy of the stand. An alternative is to cut or kill a sufficient number of large diameter stems to recreate the desired stand structure immediately.

Restoration ecology may be defined as active management that seeks to return a ‘degraded’ system to the structure, composition, and disturbance regime of some reference time or ecosystem (after Wagner and others 2000). This ‘reference state’ is often defined as that which existed pre-European settlement. Thus, restoration ecology actively manipulates a system to achieve a desired vegetative

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Table 1—Pre-treatment overstory measurements

	Basal area (ft^2/acre)	Stocking (percent)	Canopy cover (percent)	Light transmission (percent)
Savanna 1	112.5 ± 11.8	100.2 ± 7.8	80	14.4 ± 12.3
Savanna 2	79.4 ± 7.1	69.6 ± 5.5	71	25.8 ± 28.3
Savanna 3	152.5 ± 22.5	120.2 ± 13.4	99	4.4 ± 3.9

state. In the same vein, silviculture is defined as the art and science of controlling the establishment, growth, composition, health, and quality of forests and woodlands to meet the diverse needs and values of landowners and society on a sustainable basis (Helms 1998). In other words, active manipulation of forest stands to meet landowner objectives. Wagner and others (2000) suggest that restoration differs from silviculture in that it substitutes a reference condition for specific objectives. This seems to be a difference without real substance. If a landowner lists as an objective the creation of some reference condition, the silviculturist can develop a prescription to achieve that end, subject to the same constraints as any other objective (i.e. is the objective biologically possible, is it mutually exclusive of another stated objective, are there sufficient resources to achieve the stated objective, etc…). Such prescriptions have been written and implemented for restoration of pre-settlement ponderosa pine habitat (Lynch and others 2000) and for creating/restoring optimal goshawk habitat (Long and Smith 2000). As an added bonus, the silvicultural methods used to arrive at the desired vegetative state may generate income to the landowner.

The Sinkin Experimental Forest is used primarily for research and demonstration. This demonstration site was not intended nor was it designed to be a formal experiment or comparison. There is no true statistical replication and the prescribed burns were not implemented or monitored in sufficient detail to draw conclusions about cause and effect. We initiated this project to demonstrate techniques and evaluate the efficacy of reducing stand density and reintroducing fire in order to develop the tree composition and structure and herbaceous complex typical of a savanna/oak-woodland. It was also designed to show small landowners another option for land management where timber production may not be the driving force on a parcel, especially in an area where oak decline is or might be a problem.

Table 2—Post-treatment overstory measurements

		Basal area (ft^2/acre)	Stocking (percent)	Light transmission (percent)
Savanna 1	1999	35.5	33.4	73
	2000	32.8	29.1	74
Savanna 2	1999	26.9	27.4	67
	2000	25.6	24.3	79
Savanna 3	1999	35.3	21.2	75
	2000	29.0	17.4	83

METHODS

Site Description

The savanna demonstration area consists of three separate stands on the Sinkin Experimental Forest, which is located in south central Missouri in the Ozark Highlands. Savanna 1 is approximately 2.75 acres in size and is located on an upper slope with a western aspect. The site index is 60-65 feet (for black oak, base age 50 years) and the pretreatment overstory was composed primarily of black oak, white oak, post oak, and hickory (average age 95 years). The midstory and understory tree species were primarily black gum, dogwood, and sassafras. During the 1998 growing season, this stand supported approximately 108 feet^2/acre of basal area (all trees = 1.6 inches DBH) (table 1).

Savanna 2 is 4 acres in size and lies on a southwest facing upper slope. The overstory was dominated by 85-year-old scarlet oak, black oak, white oak, and shortleaf pine. Like savanna 1 the site index was in the low 60's. Understory trees were principally hickory, black gum, and dogwood. This stand had been affected by oak decline, there were several large dead or dying scarlet and black oaks; this reduced standing density to approximately 80 feet^2/acre basal area. Because of the relatively low density of this stand, there was a well-developed understory and midstory of oak advance reproduction and woody shrubs.

Savanna 3 covers 3 acres on an upper west-facing slope. It was the only shortleaf pine dominated site. The trees were approximately 80 years old and the site index was estimated at 65 feet. Smaller pole sized trees in this stand included white oak, post oak, black oak, scarlet oak, hickory, black gum, and dogwood. There were few subcanopy or understory trees in this stand, probably due to the high density (153 feet^2/acre basal area).

Measurements

In each of the three stands, a pre-treatment inventory of the overstory and understory was made during the 1998 growing season. Three circular one-third acre overstory plots were established on each site and all trees = 1.6 inches DBH were tallied by species and DBH. Post-treatment inventories were conducted during the 1999 and 2000 growing seasons.

Data on all understory woody stems (< 1.6 inches DBH) was collected on 96 one-five hundredth acre circular subplots (24, 36, and 36 plots on savannas 1, 2, and 3, respectively). This vegetation was tallied by species, origin, height class, and number of stems. Herbaceous and semi-woody stems were sampled in a one square-meter frame located at an azimuth of 90 degrees and 2 meters distance from subplot center. All vegetation was tallied by species, height class, and percent cover.

Canopy closure was measured at each subplot center with a densitometer. In addition, canopy photographs were taken using an 18mm lens and PAR (photosynthetically active radiation) was sampled with a sunfleck ceptometer.

Prescription

Our target overstory structure was to have approximately 35 feet^2/acre of large, well-spaced trees. This density would equate to approximately 50 percent canopy closure if the trees had been open grown (Law and others 1994). However, since the initial stands were fairly high density, closed canopy stands, the crowns of the residual stems were less developed than open grown trees and the resulting canopy closure would be reduced. As the residual overstory trees expand their crowns, adjustments to stand density will be made in future years to ensure that canopy closure remains within the 10 to 50 percent range cited as typical for Missouri Ozark savanna systems (Nuzzo 1986).

Table 4—Pre-treatment herbaceous plants inventoried

Species	Species
Virginia creeper	
Desmodium	New jersey tea
Wild grape	False solomans seal
Blackberry	American feverfew
Vaccinium	Horseweed
Carolina rose	Horse mint
Helianthus	False buck wheat
Poison ivy	Panicum spp.
Oxalis	Panicum ravenellii
Carex spp.	Panicum commutatum
Carex complinata	Panicum lanuginosum
Bracken fern	Dittany
Cinquefoil	Pussy's toes
Solidago	Lespedeza
Aster spp.	Broom sedge
Aster turbinellus	Bedstraw
Poverty grass	Corral berry
Wood angelica	Goats rue
Hog peanut	Green briar
Milkweed	Rue anemone
Violet	Flowering spurge
False flax	Meadow parsnip
Virginia snake root	Christmas fern

Following the pretreatment inventory, the three study sites were marked to leave approximately 40 feet^2/acre of basal area in all stems = 1.6 inches DBH. Leaving 40 feet^2/acre allowed for compensation based on mortality caused by logging damage or the prescribed fire. Leave trees were selected based on canopy dominance, species, vigor, and spacing.

Table 3—Understory woody stem density (< 1.6 inches DBH) averaged across all three sites

	Pre-treatment (stems per acre)	Post-treatment burn 1 (stems per acre)	Post-treatment burn 2 (stems per acre)
White oak	711	763	323
Black oak	1593	1033	942
Scarlet oak	407	513	478
Post oak	142	228	844
Hickories	527	561	927
Black cherry	176	92	43
Black gum	619	1169	1918
Red maple	335	132	100
Dogwood	713	314	340
Sassafras	1065	2956	1487
Sumac	38	478	840
Savanna 2 only			
Wild plum	14	24	0
Shortleaf pine	359	85	143

Table 5—Newly occurring herbaceous species following treatment

Species	Species
Fireweed	Black haw
Pokeweed	Fake dandelion
Nightshade	Juncos tenius
Goats rue	Ambrosia
Wild strawberry	Big blue stem
Little blue stem	Partridge pea
Hawk weed	Queen Anne's lace
Kentucky blue grass	Fimbristylis
Skull cap	Dogbane
Wild indigo	Wild geranium
Violet	Prickly lettuce
Wild oat grass	Angle pod
False buckwheat	Trailing milk pea
Aromatic sumac	Horse nettle
Pink wild bean	

The largest trees of the most fire resistant species were preferentially left in the stand. During the 1998-99 dormant season, the three stands were thinned. A horse logger was contracted to conduct the harvest for two reasons. First, the total area treated and the volume removed were relatively small. The logger was willing to bid on this sale and was able to complete the project on our timetable. More importantly, the site impact from horse logging is minimal. The horses are able to maneuver in a partially cut stand better than most skidders (residual stand damage was almost non-existent) and upon completion of the harvest operation, the main skid trail looked more like a backcountry hiking trail than a skid trail.

A prescribed burn was conducted on April 7, 1999. Mortality was assessed and the residual basal area was adjusted to 35^{2}feet/acre in May 1999. A second prescribed burn was conducted in April of 2000. There was difficulty in getting the fire to carry across the stands during the second year burn because of low fuel loads and discontinuous fuels. For this reason, future burns will be conducted every other year following an assessment of the fuel conditions on each site.

RESULTS AND DISCUSSION

Overstory

As was mentioned, our target overstory density was 35 feet^2/acre of basal area. Following initial treatments, savannas 1 and 3 were extremely close to the mark at 35.5 and 35.3 feet^2/acre, respectively (table 2). Savanna 2 is somewhat under stocked because of the large incidence of oak decline on this site in the black and scarlet oak components. This stand had somewhat higher fire related mortality, probably due to the higher fuel loads that were caused by the relatively low initial density and subsequently higher light transmission into the understory, which caused a buildup in understory vegetation.

Notice that the stocking percentage is very different between savannas 1 and 3 even though the residual basal area is nearly the same (table 2). Many smaller diameter stems were left on savanna 1 to meet residual stocking demands, which were able to be met with fewer large diameter stems on savanna 3. This difference in overstory structure will also affect percent canopy closure and light transmittance through the canopy. Unless fire related mortality preferentially affects the smaller diameter trees on savanna 1 in the future, additional thinning may be required in this stand first to maintain the desired open structure.

Some additional mortality did occur between years 1 and 2, but this was likely the result of our current drought exacerbating the oak decline problem rather than a direct result from the prescribed fires. At the end of 2000, the Sinkin Experimental Forest had a cumulative 2-year precipitation deficit of nearly 24 inches from a 50-year average annual precipitation rate of 44 inches (data on file at the Columbia Forest Science Lab, Columbia, MO).

Understory

The prescribed fires caused some marked and immediate changes in the understory (< 1.6 inches DBH) woody components of these stands (table 3). Except for the marginal effect of the removal of the overstory trees on these stems (nothing < 1.6 inches DBH was cut during the thinning operation) the change in density was caused primarily by the prescribed fire. Species that experienced large reductions in numbers include: black cherry (-75 percent), dogwood (-52 percent), red maple (-70 percent), shortleaf pine (- 60 percent), and blackhaw was eliminated from the understory. Similarly, some species greatly benefited from the introduction of fire: black gum (+210 percent), sassafras (+40 percent), sumac (+2110 percent), and post oak (494 percent).

Without regard to the direction of change in woody understory numbers, the general dynamic seems to be similar to that reported by Blake and Schuette (2000). The largest of the understory stems have been eliminated. Although many of these stems are resprouting from the root collar (unreported data), it seems that the recruitment of reproduction into the overstory will be reduced or eliminated with regular prescribed fire. Thus, if the disturbance regime (regular fire) is continued, it should be sufficient to maintain the desired overstory structure. However, it should be noted that episodic fire free intervals will be needed at some time in the future so sufficient reproduction can be recruited into the overstory to replace trees lost to mortality.

Herbaceous Vegetation

Pretreatment inventories tallied over 45 herbaceous and semi-woody understory species (table 4). Following the initial treatment (cut and burn), an additional 20 species were identified on the sites. After the second prescribed burn, another 17 species were found (table 5). Following the first year's treatment, 8 species were eliminated from the study sites: Virginia snake root, poverty grass, corral berry, Christmas fern, bedstraw, meadow parsnip, green briar, and rue anemone. However, during the second inventory following treatment, last 4 of these species once again showed up on our tally.

Fireweed and pokeweed arrived in profusion across all of the study sites following the first year's treatment and increased markedly in prominence following the second prescribed fire. By August 2000, fireweed occurred on 82 percent of our subplots with an average cover of 10 percent. Pokeweed appeared on 21 percent of the plots and averaged 14 percent cover. Six other species were fairly common: nightshade (6 percent of plots, 3 percent cover), little blue stem (13, 5), goat's rue (3,9), hawk weed (8, 3), wild strawberry (6, 3), and hog peanut (5, 3). The speed these sites were colonized was somewhat surprising given the fact that they have been under a closed canopy forest for over 40 years and continuous forest cover currently surrounds them for several miles. Either the seed source for these plants is amazingly persistent in the soil, or they have mechanisms for traveling great distance.

CONCLUSIONS

Silviculture need not have timber production as an exclusive (or even primary) objective. The goal is to produce a forest vegetative state that meets the objectives of the landowner. In the case of restoration, that objective is some historical or reference state. Our objective on this demonstration area was to develop the tree composition, structure, and herbaceous complex typical of a savanna. To achieve this goal, a prescription was designed to re-create the overstory structure typical of a pre-settlement Missouri savanna (Nuzzo 1986) and reintroduce the disturbance regime (periodic fire) that historically maintained the reference ecosystem. Initial treatments greatly modified the forest overstory structure, and reduced the litter layer, midstory and shrub layers, greatly increasing light levels at the forest floor. In turn, this has affected an immediate and marked shift in the understory complex of herbaceous and woody plants, nearly doubling the species diversity within two years of initial treatment.

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